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U1S S2101 S2119

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US 5756202 A US 5688380 A US 5607740 A
US 5580667 A US 5051288 A

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Online: WPI, EPODOC, JAPIO

(71) Applicant(s)
International Business Machines Corporation
(Incorporated in USA - New York)
Armonk, New York 10504, United States of America

(72) Inventor(s)
Matthew Joseph Carey
Eric Edward Fullerton
Bruce Alvin Gurney
Hal Jervis Rosen
Manfred Ernst Schabes

(74) Agent and/or Address for Service
C J Ling
IBM United Kingdom Limited, Hursley Park, WINCHESTER, Hampshire, SO21 2JN, United Kingdom

(54) Abstract Title
Magnetic recording media with antiferromagnetically coupled ferromagnetic film

(57) A magnetic recording medium for data storage uses a magnetic recording layer having at least two ferromagnetic films antiferromagnetically coupled together across a nonferromagnetic spacer film. The magnetic moments of the two antiferromagnetically-coupled films are oriented antiparallel, and thus the net remanent magnetisation-thickness product (Mrt) of the recording layer is the difference in the Mrt values of the two ferromagnetic films. This reduction in Mrt is accomplished without a reduction in the thermal stability of the recording medium because the volumes of the grains in the antiferromagnetically-coupled films add constructively. In a magnetic recording rigid disk application, the magnetic layer comprises two ferromagnetic films, each a granular film of a sputter deposited coPtCrB alloy, separated by a Ru spacer film having a thickness to maximise the antiferromagnetic exchange coupling between the two CoPtCrB films. One of the ferromagnetic films is made thicker than the other, but the thicknesses are chosen so that the net moment in zero applied magnetic field is low, but nonzero. In general the first and second ferromagnetic films are made of a material selected from Co, Fe, Ni and their alloys. Apart from ruthenium the spacer film may be formed of Cr, Rh, Ir, Cu and their alloys. The medium may be in the form of a disk which has an underlayer on the substrate and a protective overcoat formed on the magnetic recording layer.

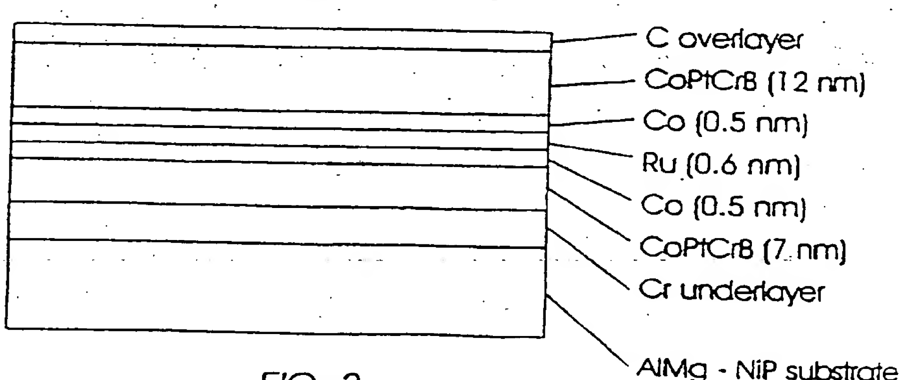


FIG. 3

GB 2 355 018 A

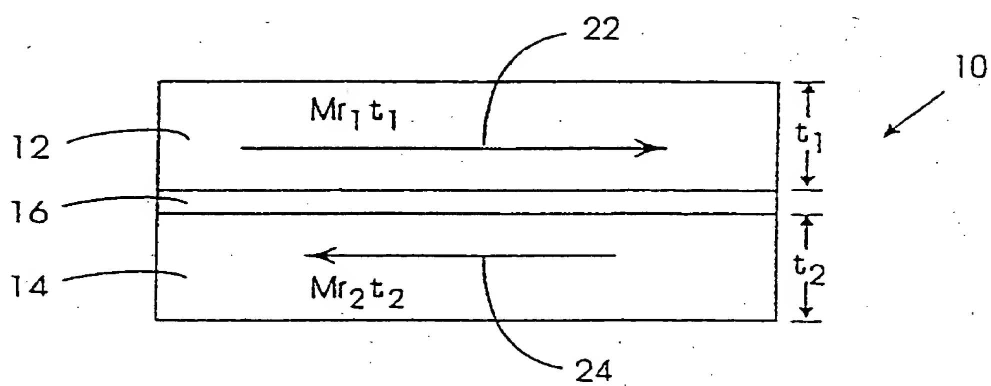
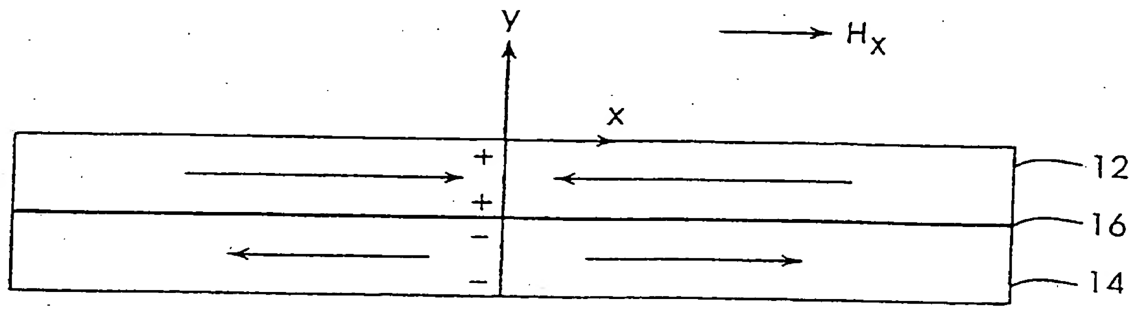
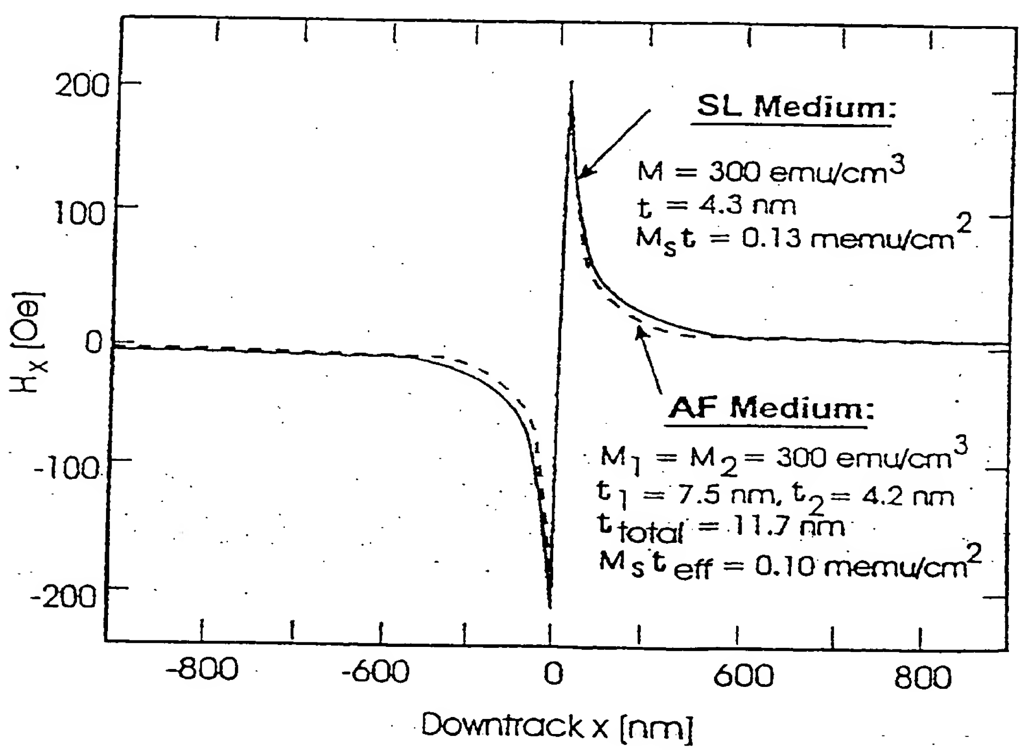


FIG. 1



y
H_x
x
+
+
−
−
12
16
14

FIG. 2A



200
100
0
-100
-200
H_x [Oe]
-800
-600
0
600
800
Downtrack x [nm]
SL Medium:
M = 300 emu/cm3
t = 4.3 nm
Ms t = 0.13 memu/cm2
AF Medium:
M1 = M2 = 300 emu/cm3
t1 = 7.5 nm, t2 = 4.2 nm
ttotal = 11.7 nm
Ms teff = 0.10 memu/cm2

FIG. 2B

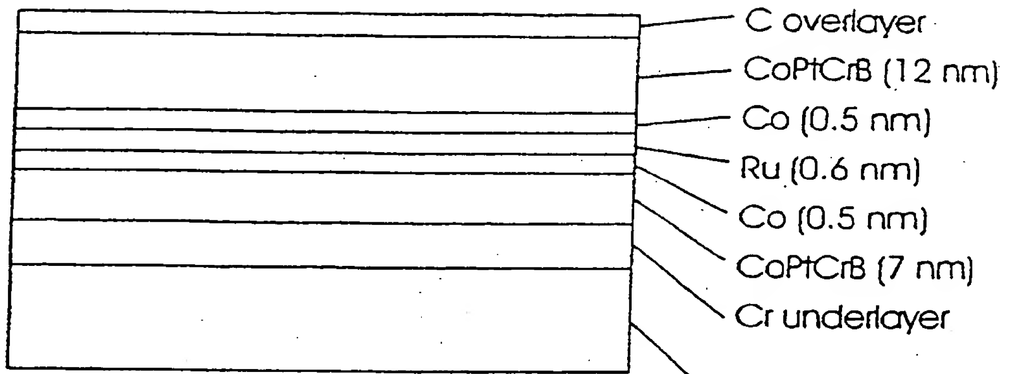

C overlayer
CoPtCrB (12 nm)
Co (0.5 nm)
Ru (0.6 nm)
Co (0.5 nm)
CoPtCrB (7 nm)
Cr underlayer
AlMg - NiP substrate

FIG. 3

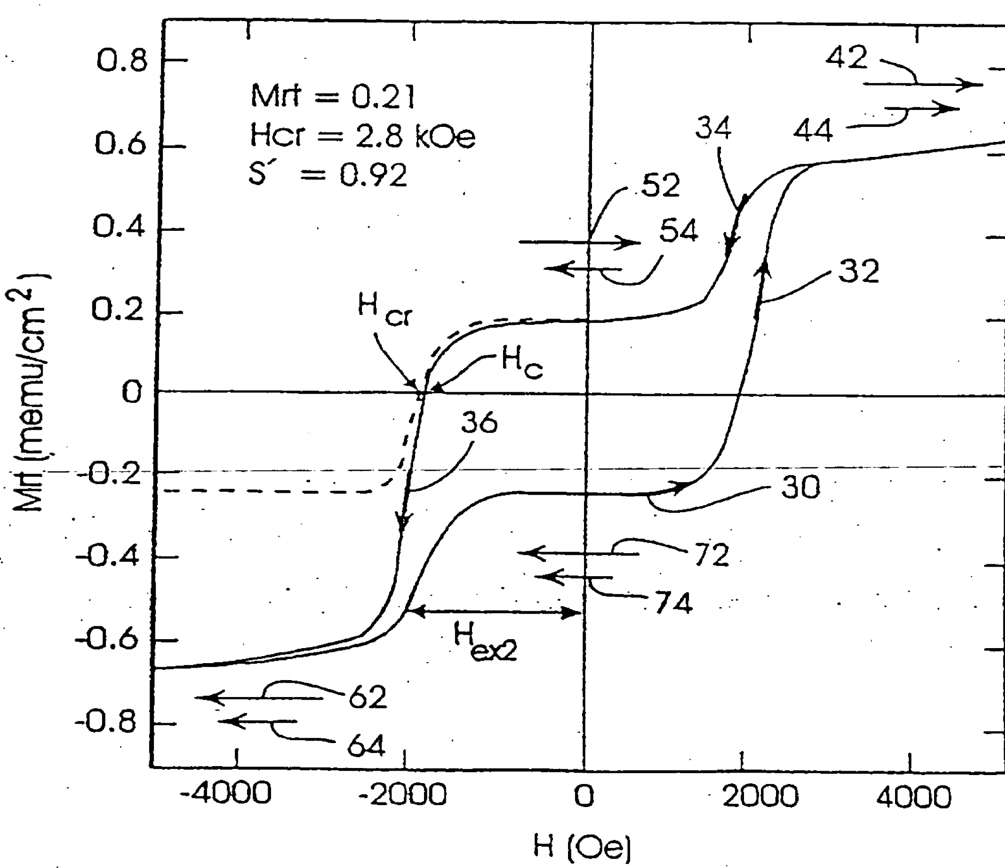

Mrt = 0.21
Hcr = 2.8 kOe
S´ = 0.92
Mrt (memu/cm2)
H (Oe)
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-4000
-2000
0
2000
4000
42
44
34
52
54
32
Hcr
Hc
36
30
72
74
Hex2
62
64

FIG. 4

2355018

MAGNETIC RECORDING MEDIA WITH ANTIFERROMAGNETICALLY COUPLED FERROMAGNETIC FILMS AS THE RECORDING LAYER

Field of the Invention

This invention relates generally to magnetic recording media, and more particularly to thermally stable high density media.

Background of the Invention

Conventional magnetic recording media, such as the magnetic recording disks in hard disk drives, typically use a granular ferromagnetic layer, such as a sputter-deposited cobalt-platinum (CoPt) alloy, as the recording medium. Each magnetised domain in the magnetic layer is comprised of many small magnetic grains. The transitions between magnetised domains represent the "bits" of the recorded data. IBM's US patents 4,789,598 and 5,523,173 describe this type of conventional rigid disk.

As the storage density of magnetic recording disks has increased, the product of the remanent magnetisation Mr (the magnetic moment per unit volume of ferromagnetic material) and the magnetic layer thickness t has decreased. Similarly, the coercive field or coercivity (H_c) of the magnetic layer has increased. This has led to a decrease in the ratio Mrt/H_c. To achieve the reduction in Mrt, the thickness t of the magnetic layer can be reduced, but only to a limit because the layer will exhibit increasing magnetic decay, which has been attributed to thermal activation of small magnetic grains (the superparamagnetic effect). The thermal stability of a magnetic grain is to a large extent determined by K_uV, where K_u is the magnetic anisotropy constant of the layer and V is the volume of the magnetic grain. As the layer thickness is decreased, V decreases. If the layer thickness is too thin, the stored magnetic information will no longer be stable at normal disk drive operating conditions.

One approach to the solution of this problem is to move to a higher anisotropy material (higher K_u). However, the increase in K_u is limited by the point where the coercivity H_c , which is approximately equal to K_u/Mr, becomes too great to be written by a conventional recording head. A similar approach is to reduce the Mr of the magnetic layer for a fixed layer thickness, but this is also limited by the coercivity that can be written. Another solution is to increase the intergranular exchange, so that the effective magnetic volume V of the magnetic grains is increased.

However, this approach has been shown to be deleterious to the intrinsic signal-to-noise ratio (SNR) of the magnetic layer.

What is needed is magnetic recording media that will support very high density recording while retaining good thermal stability and SNR.

Disclosure of the Invention

The invention is a magnetic recording medium wherein the magnetic recording layer is at least two ferromagnetic films antiferromagnetically coupled together across a nonferromagnetic spacer film. Because the magnetic moments of the two antiferromagnetically-coupled films are oriented antiparallel, the net remanent magnetisation-thickness product (Mrt) of the recording layer is the difference in the Mrt values of the two ferromagnetic films. This reduction in Mrt is accomplished without a reduction in the thermal stability of the recording medium because the volumes of the grains in the antiferromagnetically-coupled films add constructively. The medium also enables much sharper magnetic transitions to be achieved with reduced demagnetisation fields, resulting in a higher linear bit density for the medium. In one embodiment the magnetic recording medium comprises two ferromagnetic films, each a granular film of a sputter deposited CoPtCrB alloy, separated by a Ru spacer film having a thickness to maximize the antiferromagnetic exchange coupling between the two CoPtCrB films. One of the ferromagnetic films is made thicker than the other, but the thicknesses are chosen so that the net moment in zero applied magnetic field is low, but nonzero.

For a fuller understanding of the nature and advantages of the present invention, reference should be made to the following detailed description taken together with the accompanying figures.

Brief Description of the Drawings

Fig. 1 is a schematic sectional view of the antiferromagnetically (AF) coupled magnetic recording layer in a recording medium according to the present invention;

Fig. 2A is a schematic illustration of the AF-coupled layer illustrating the orientations of the moments of the ferromagnetic films at a recorded magnetic transition;

Fig. 2B is a graph of calculated magnetic field above the AF-coupled layer and a single layer (SL) medium as a function of downtrack position from a transition;

Fig. 3 is a schematic sectional view of the disk structure of the present invention illustrating the substrate, underlayer, the films in the AF-coupled layer, and the protective overcoat; and

Fig. 4 is a magnetic hysteresis loop for the structure with the AF-coupled layer of Fig. 3.

Detailed Description of the Invention

The magnetic recording medium of the present invention has a recording layer formed of two or more ferromagnetic films that are exchange-coupled antiferromagnetically (AF) to their neighbouring ferromagnetic films by one or more nonferromagnetic spacer films. This is shown schematically in Fig. 1 for a recording layer 10 made up of two ferromagnetic films 12, 14 separated by a nonferromagnetic spacer film 16. The nonferromagnetic spacer film 16 thickness and composition are chosen so that the magnetic moments 22, 24 of adjacent films 12, 14, respectively, are AF-coupled through the nonferromagnetic spacer film 16 and are antiparallel in zero applied fields.

The AF coupling of ferromagnetic films via a nonferromagnetic transition metal spacer film has been extensively studied and described in the literature. In general, the exchange coupling oscillates from ferromagnetic to antiferromagnetic with increasing spacer film thickness. This oscillatory coupling relationship for selected material combinations is described by Parkin et al. in "Oscillations in Exchange Coupling and Magnetoresistance in Metallic Superlattice Structures: Co/Ru, Co/Cr and Fe/Cr", *Phys. Rev. Lett.*, Vol. 64, p. 2034 (1990). The material combinations include ferromagnetic films made of Co, Fe, Ni, and their alloys, such as Ni-Fe, Ni-Co, and Fe-Co, and nonferromagnetic spacer films such as ruthenium (Ru), chromium (Cr), rhodium (Rh), iridium (Ir), copper (Cu), and their alloys. For each such material combination, the oscillatory exchange coupling relationship has to be determined, if not already known, so that the thickness of the nonferromagnetic spacer film is selected to assure antiferromagnetic coupling between the two ferromagnetic films. The period of oscillation depends on the nonferromagnetic spacer material, but the strength and phase of the oscillatory coupling also depends on the ferromagnetic material and interfacial quality. The oscillatory antiferromagnetic coupling of ferromagnetic films has been used

in spin-valve type giant magnetoresistance (GMR) recording heads to design continuous magnetised antiferromagnetically coupled films whose magnetic moments are rigidly coupled together antiparallel during operation of the head. These type of spin-valve structures are described, for example, in IBM patents 5,408,377 and 5,465,185. The '185 patent describes a structure used in many commercially available spin-valve GMR heads, namely a laminated antiparallel pinned ferromagnetic layer having ferromagnetic films whose moments are rigidly coupled together and remain stationary during operation of the head.

The films 12, 14 have magnetic moment values of $Mr_1 t_1$ and $Mr_2 t_2$, respectively. (Because the remanent magnetisation Mr is expressed as the magnetic moment per unit volume of ferromagnetic material, the product Mrt is the magnetic moment per unit area for a magnetic layer of thickness t.) For this AF-coupled structure the orientations of the magnetic moments 22, 24 of adjacent films 12, 14, respectively, are aligned antiparallel and thus add destructively to reduce the magnetic moment of the composite layer 10. The arrows 22, 24 represent the moment orientations of individual magnetic domains that are directly above and below one another across the AF coupling film 16. In the absence of an applied magnetic field, when the ferromagnetic film 14 is deposited onto the medium substrate, it will have a granular structure with multiple adjacent grains being coupled together to form individual magnetic domains. In the absence of an applied magnetic field the moments of these domains in film 14 will be essentially randomly oriented. The spacer film or AF-coupling film 16 is then deposited to the correct thickness directly on ferromagnetic film 14. Next , the second ferromagnetic film 12 is deposited directly on the AF coupling film 16. As the grains of ferromagnetic film 12 grow they will form magnetic domains with moment orientations that are antiparallel to the moment orientations of ferromagnetic film 14 that are directly across the AF coupling film 16.

The type of ferromagnetic material and the thickness values t_1, t_2 of the ferromagnetic films 12, 14 are chosen so that the net moment in zero applied field will be low, but nonzero. For the case shown in Fig. 1, the Mrt for the structure is given by $Mr_1 t_1 - Mr_2 t_2$. In the preferred embodiment, $Mr_1 t_1$ should be $> Mr_2 t_2$. This may be accomplished by using the same ferromagnetic materials in the two films 12, 14 and having t_1 be greater than t_2, or the magnetisation (the magnetic moment per unit volume of material) of the two ferromagnetic films may be made different by using different ferromagnetic materials for the two films. While Fig. 1 is shown for a two-film structure with a single spacer film 16, the invention is

extendible to structures with multiple spacer films and multiple ferromagnetic films.

The present invention has a number of advantages over a magnetic layer formed as a single layer of ferromagnetic material. Low remanent magnetisation can be obtained without using ultra-thin magnetic layers or low-magnetisation alloys. This avoids the problems of thermal instability and difficulty in writing discussed above. If the magnetic layer in Fig. 1 is compared to a single-layer consisting of only film 12, for example, the addition of the AF-coupled ferromagnetic film 14 reduces the net magnetic moment of the composite structure without decreasing either the thickness or the magnetisation of film 12.

The enhanced thermal stability of the composite structure compared to a single magnetic layer arises because the anisotropy of the grains in both films 12 and 14 are substantially uniaxial, and thus can add constructively even if the magnetic moments of films 12, 14 are antiparallel. The resulting stability parameter of the coupled system K_uV is given by $Ku_1V_1 \backslash KuV \backslash (Ku_1V_1+Ku_2V_2)$, where Ku_1V_1 and Ku_2V_2 are the anisotropy energies of typical grains in films 12, 14, respectively. The upper limit for the composite stability parameter $KuV = Ku_1V_1+Ku_2V_2$ will be achieved for the case when magnetic grains in film 12 and 14 are strongly coupled and share a common anisotropy axis direction. The magnetic volume V of the composite structure (layer 10) that determines the thermal stability will be approximately the sum of the volumes of the exchange-coupled grains in films 12 and 14, whereas the magnetic moment of layer 10 is the difference of the individual moments of films 12, 14. The antiferromagnetic coupling between the two ferromagnetic films provides a mechanism to increase the effective film thickness while reducing the net Mrt value of the composite structure. Thus the ferromagnetic films can contain very small diameter grains and maintain thermal stability.

The AF-coupled medium according to the present invention is shown schematically in Fig. 2A with a recorded or written magnetic transition. The plus (+) and minus (-) symbols represent the magnetic poles arising from the transition. The calculated longitudinal field (H_x) 10 nm above the surface of the AF-coupled medium is shown in Fig. 2B as a function of X direction or downtrack position from the transition. The moment and thickness values for the two films 12, 14 and the calculated Mrt for the AF-coupled layer are listed in Fig. 2B. For comparison, Fig. 2B also shows model calculations of longitudinal magnetic field arising from transitions

in a single-layer (SL) medium that has a similar Mrt. The thickness values (t_1 and t_2) were chosen such that the peak longitudinal field was the same for the AF-coupled medium compared to the SL medium. The total thickness of the ferromagnetic material in the AF-coupled medium is 2.7 times thicker. Therefore, the AF-coupled medium should be more thermally stable than the SL medium. The longitudinal field profile in the downtrack direction decays faster for the AF-coupled medium, resulting in a sharper transition. This indicates that the transitions can be spaced closer than in the SL medium, resulting in a higher linear bit density for the medium. While not shown in Fig. 2B, calculations have also shown that the demagnetisation field from a transition within the AF-coupled medium also decreases faster than in the SL medium. In addition, the magnitude and sign of the demagnetisation field depends on the Y position (see Fig. 2A) within the medium. Thus for certain Y positions within the medium, the demagnetisation field is reduced to zero. Small demagnetisation fields are desired because they can affect other transitions and cause the transition to demagnetise itself.

The present invention has been demonstrated using conventional CoPtCrB longitudinal recording media alloys for the ferromagnetic films. An example structure is shown in Fig. 3. The structure was fabricated using conventional sputter deposition equipment and processes. The films forming the structure were grown onto a Cr underlayer deposited onto a substrate of a AlMg disk blank with a nickel-phosphorous (NiP) surface coating, with the substrate temperature at approximately 200 âC. The ferromagnetic films are CoPtCrB, with the top film corresponding to film 12 in Fig. 1 being thicker than the bottom ferromagnetic film corresponding to film 14 in Fig. 1 (12 nm vs. 7 nm). The nonferromagnetic spacer film is a 0.6 nm Ru film. As with single-layer media, it is advantageous to use a granular ferromagnetic material with isolated magnetic grains to lower the media noise. The Ru film thickness was chosen to be at the first antiferromagnetic peak in the oscillatory coupling relationship. For this example, each CoPtCrB ferromagnetic film included an interface film consisting essentially of 0.5 nm of Co at the interface with the Ru film. These ultra-thin Co films increase the interfacial moment between the ferromagnetic films and the Ru film, resulting in enhanced antiferromagnetic coupling. However, antiferromagnetic exchange coupling has been demonstrated without incorporating the Co interface films in the CoPtCrB ferromagnetic films.

Fig. 4 shows the major hysteresis loop (solid line) and the remanent hysteresis loop (dashed line) measured at T=350 âK for the structure of Fig. 3. Referring first to the remanent hysteresis loop, it is obtained by saturating the AF-coupled layer in a positive field and then applying an increasing reverse negative field and measuring the remanent moment in the layer after the negative field is applied. The remanent loop is a plot of the remanent moment versus the magnitude of the reverse field. For this sample the remanent loop shows Mrt=0.21, the remanent coercive field H_{cr}=3.2 kOe, and S'=0.92 at room temperature, where S' is a measure of the slope of the remanent loop at H_{cr}. For comparison, a similarly grown 15-nm single layer of the same CoPtCrB alloy has properties of Mrt=0.38, H_{cr}=2.4 kOe and S'=0.76 at room temperature. Thus, the AF-coupled medium allows a significantly lower Mrt to be achieved with a greater total magnetic layer thickness.

Referring next to the major hysteresis loop of Fig. 4, the pairs of horizontal arrows indicate the orientation of the ferromagnetic films in the AF-coupled layer at different points in the hysteresis loop. The applied field is increased in the positive direction (arrows 30, 32). For large applied fields (>3000 Oe), the antiferromagnetic coupling is overcome and the moments of the two ferromagnetic films are both parallel to the applied field (arrows 42, 44). As the applied field is reduced (arrow 34) the moment of the thinner bottom ferromagnetic film reverses and becomes antiparallel to the moment of the thicker top ferromagnetic film (arrows 52, 54) and to the applied field with a drop in the net moment. This switch occurs roughly at the exchange field felt by the bottom film (H_{ex2}=2000 Oe) arising from the coupling across the Ru film. The value of $H_{ex2} = J_{ex}/M_2 t_2$, where J_{ex} is the antiferromagnetic interface exchange energy density across the Ru spacer layer and M_2 and t_2 are the magnetisation and thickness of the bottom ferromagnetic film, respectively. For an antiparallel alignment of the ferromagnetic films to be realised requires that H_{ex2} exceed the coercive field required to reverse the bottom ferromagnetic film (H_{c2}). H_{c2} is the coercive field of the bottom film, assuming no exchange interaction with the top ferromagnetic film. Thus, the magnetic properties and thickness of the bottom film, as well as the AF-coupling film, must be designed to maintain $H_{ex2}>H_{c2}$.

The remanent state after saturation in a positive field is given by the moment of the top ferromagnetic film parallel to the field direction and the moment of the bottom ferromagnetic film antiparallel to the positive field direction (arrows 52, 54). In a reverse applied field

(arrow 36), the magnetic state is stable until the moment of the top ferromagnetic film reverses and the moments of both films are parallel and aligned in the negative saturation state (arrows 62, 64). The switching of the moment of the top ferromagnetic film determines the coercive field of the AF-coupled layer and is given by $H_c = H_{ex1} + H_{c1}$ where H_{ex1} is the exchange field acting on the top ferromagnetic film ($H_{ex1}=J_{ex}/M_1t_1$) and H_{c1} is the coercive field of the top ferromagnetic film, assuming no interaction with the bottom ferromagnetic film. Thus, the properties of the top ferromagnetic film and the AF-coupling film must be designed to maintain H_c of the composite structure below the expected write field of the head. For this example the pathway to go from one remanent state (arrows 52, 54) to the next remanent state (arrows 72, 74) goes through an intermediate state where the moments of the two films are parallel (arrows 62, 64). Thus, in contrast to AF-coupled structures used in spin-valve GMR recording heads, the moments of the ferromagnetic films in the medium according to the present invention are not rigidly coupled together across the AF-coupling film because the coupling must be overcome to write on the medium. The hysteresis loop of Fig. 4 exhibits the desired feature of an AF-coupled layer, i.e., a low remanent magnetisation relative to the saturation magnetisation.

Recording performance tests on the AF-coupled layer were performed using a conventional longitudinal recording head. Signal to noise ratio measurements determined a media S_oNR of 31.9 dB at 9500 flux changes per millimetre (fc/mm), where S_o is the isolated pulse amplitude and N is the integrated media noise at 9500 fc/mm recording density. These results demonstrate the viability of AF-coupled magnetic layers for data storage.

~~The AF-coupled media according to the present invention has also been~~ demonstrated for structures with and without one or both Co interface films, with and without one or both CoCr interface layers, and with CoCrPtTa ferromagnetic films.

CLAIMS

1. A magnetic recording medium comprising:

a substrate;

a magnetic recording layer on the substrate and comprising a first ferromagnetic film, a nonferromagnetic spacer film on the first ferromagnetic film, and a second ferromagnetic film on the spacer film, the second ferromagnetic film being exchange coupled antiferromagnetically to the first ferromagnetic film across the spacer film.

2. A medium as claimed in claim 1 further comprising a second nonferromagnetic spacer film on the second ferromagnetic film and a third ferromagnetic film on the second spacer film, the third ferromagnetic film being exchange coupled antiferromagnetically to the second ferromagnetic film across the second spacer film.

3. A medium as claimed in claim 1 wherein the first ferromagnetic film has a thickness t1 and a magnetisation M1, the second ferromagnetic film has a thickness t2 and a magnetisation M2, and wherein the magnetic moments per unit area (M1 x t1) and (M2 x t2) of the first and second ferromagnetic films, respectively, are different from one another.

4. A medium as claimed in claim 3 wherein the first and second ferromagnetic films are formed of the same material, and wherein t1 is different from t2.

5. A medium as claimed in claim 3 wherein the first and second ferromagnetic films are formed of different materials and wherein t1 and t2 are substantially the same thickness.

6. A medium as claimed in of claim 1 wherein the spacer film is formed of a material selected from the group consisting of ruthenium (Ru), chromium (Cr), rhodium (Rh), iridium (Ir), copper (Cu), and their alloys.

7. A medium as claimed in claim 1 wherein the first and second ferromagnetic films are made of a material selected from the group consisting of Co, Fe, Ni, and their alloys.

8. A medium as claimed in claim 1 wherein the first ferromagnetic film includes an interface film consisting essentially of cobalt located at the interface of the first ferromagnetic film and the spacer film.

9. A medium as claimed in claim 1 wherein the second ferromagnetic film includes an interface film consisting essentially of cobalt located at the interface of the second ferromagnetic film and the spacer film.

10. A medium as claimed in claim 1 further comprising an underlayer located on the substrate between the substrate and the magnetic recording layer.

11. A medium as claimed in claim 1 further comprising a protective overcoat formed over the magnetic recording layer.

12. A magnetic recording disk comprising:

a substrate;

an underlayer on the substrate;

a magnetic recording layer on the underlayer and comprising a first cobalt alloy ferromagnetic film, a nonferromagnetic spacer film of a material selected from the group consisting of ruthenium (Ru), chromium (Cr), rhodium (Rh), iridium (Ir), copper (Cu), and their alloys formed on and in contact with the first ferromagnetic film, and a second cobalt alloy

ferromagnetic film formed on and in contact with the spacer film, the spacer film having a thickness sufficient to induce the second ferromagnetic film to be exchange coupled antiferromagnetically to the first ferromagnetic film across the spacer film; and

a protective overcoat formed on the magnetic recording layer.

13. A medium as claimed in claim 12 wherein the first ferromagnetic film is a granular film having multiple magnetic domains, each domain comprising multiple grains, wherein the second ferromagnetic film is a granular film having multiple magnetic domains, each domain comprising multiple grains, and wherein the moments of magnetic domains in the second ferromagnetic film are antiferromagnetically coupled antiparallel directly across said spacer film with the moments of associated magnetic domains in the first ferromagnetic film.

14. A medium as claimed in claim 12 further comprising a second nonferromagnetic spacer film formed on and in contact with the second ferromagnetic film and a third ferromagnetic film formed on and in contact with the second spacer film, the thickness of the second spacer film being sufficient to induce the third ferromagnetic film to be exchange coupled antiferromagnetically to the second ferromagnetic film across the second spacer film.

15. A medium as claimed in claim 12 wherein the first ferromagnetic film has a thickness t1 and a magnetisation M1, the second ferromagnetic film has a thickness t2 and a magnetisation M2, and wherein the magnetic moment per unit area (M1 x t1) and (M2 x t2) of the first and second ferromagnetic films, respectively, are different from one another.

16. A medium as claimed in claim 15 wherein the first and second ferromagnetic films are formed of the same material, and wherein t1 is different from t2.

17. A medium as claimed in claim 15 wherein the first and second ferromagnetic films are formed of different materials and wherein t1 and t2 are substantially the same thickness.

18. A medium as claimed in claim 15 wherein the first ferromagnetic film includes an interface film consisting essentially of cobalt located at the interface of the first ferromagnetic film and the spacer film.

19. A medium as claimed in claim 15 wherein the second ferromagnetic film includes an interface film consisting essentially of cobalt located at the interface of the second ferromagnetic film and the spacer film.

The Patent Office

INVESTOR IN PEOPLE

Application No:	GB 0015023.5	**Examiner:**	Pete Beddoe
Claims searched:	1-19	**Date of search:**	18 October 2000

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.R): C7F (FPCR, FPCX, FPDR, FPDX); G5R (RB24C)

Int Cl (Ed.7): C23C (14/14, 14/16, 14/18, 14/20, 28/00, 28/02); G11B (5/62, 5/66, 5/84)

Other: Online: WPI, EPODOC, JAPIO

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X	US 5898549	(IBM) see esp col5 line 59 - col6 line 44 & fig 2A	1 at least
X	US 5851656	(FUJI) see esp col3 lines 10-40 & fig 1	1,4,6,16 at least
X	US 5834111	(HMT) see esp col3 line 56 - col4 line 15	1,4,5, 6,10, 11,12,16, 17 at least
X	US 5756202	(US PHILIPS) see esp embodiments & fig 1	1,5,6,17 at least
X	US 5688380	(ALPS) see esp col7 line 43 - col9 line 6, & figs 1,2,23	1,4,6,10, 11,12,16 at least
X	US 5607740	(SONY) see esp col4 lines 31-45	1,4,6,10, 11,12,16 at least
X	US 5580667	(HMT) see esp col3 line 58 - col4 line 3, col5 lines	1,4,5,6, 10,11,12, 16,17 at least

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
		E	Patent document published on or after, but with priority date earlier than, the filing date of this application.
&	Member of the same patent family		

Application No: GB 0015023.5
Claims searched: 1-19

Examiner: Pete Beddoe
Date of search: 18 October 2000

Category	Identity of document and relevant passage		Relevant to claims
X	US 5051288	(IBM) see esp col2 lines 21-33	1,4,6,16 at least
X	EP 0892393 A1	(IBM) see esp col4 line 25 - col5 line 6 & fig 2	1,4,5,6, 10,11,12, 16,17 at least
X	WO 97/34295 A1	(SEAGATE) see esp example & fig 4	1,4,6,10, 11,12,17 at least
X	WO 96/24927 A1	(CONNER) see esp p16 line 26 - p17 line 7	1,4,5,6, 10,11,12, 16,17 at least

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
		E	Patent document published on or after, but with priority date earlier than, the filing date of this application.
&	Member of the same patent family		